Deposition of hot melt and wax on surfaces

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ABSTRACT

Polyvinyl acetate (PVAc) injected into water stirring in a Britt jar partially deposits on the blade. The degree of deposition decreases with increasing temperature and with decreasing molecular weight, probably because of decreasing viscosity. The deposition tendencies of PVAc mixtures tend to be intermediate between those of their components. In contrast, wax deposits on the walls of the Britt jar, possibly because the surface area of the wall exceeds that of the blade, and deposition occurs on the first surface that the wax encounters. Mixtures of wax and PVAc exhibit a complex range of behavior, e.g., wax enhances the blade deposition of a low-molecular-weight PVAc by increasing the viscosity of the mixture. Fiber has a conflicting effect on blade deposition. On the one hand, it can add "body" to low-viscosity stickies, thereby increasing their resistance to washout; on the other, fiber can act as a scouring agent. Deposition of PVAc to the blade from white water or water containing surfactant was similar to that from water.

Application:

Conditions that lead to the deposition of mixtures of stickies and waxes from water to surfaces are discussed.

THE DEPOSITION OF STICKIES AND waxes on surfaces depends on factors such as the physical and chemical nature of the contaminant, the effect of other chemicals present, the nature of the surface, and operating conditions such as temperature and shear *(1–11)*. Identifying some of these factors is important, even if it only serves to recognize problem situations or regions in the mill that may be especially prone to stickie deposition. During previous Britt jar work on the interactions among hot melt, fiber, and water *(12)*, we noted that a portion of the stickie in the system occasionally deposited on the blade. We have studied the effect of temperature, hot-melt type and composition, consistency, and surface properties on deposition, and in this paper, we identify some of the conditions that promote the attachment of wax and stickies to surfaces. Polyvinyl acetates (PVAcs) in the 12,800–500,000 molecular weight (MW) range were used as models for the hot melts. While commercial hot-melt formulations can be more complex, these PVAcs allow study of the interactions of the base polymers.

EXPERIMENTAL

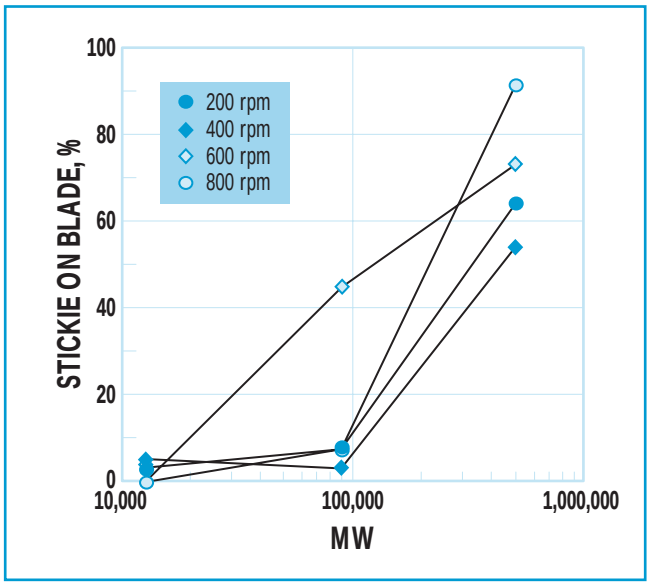
Our general experimental protocol for the hot melts was to slowly inject a 2% solution of PVAc (obtained from Aldrich or Polyscience) in methanol into 600 mL of either water or a pulp suspension stirred at 200–800 rpm in a Britt jar. Reynolds numbers at 200, 400, 600, and 800 rpm were 3.94×10^3, 7.89×10^3, 1.18×10^4, and 1.58×10^4, respectively, suggesting turbulent flow. The PVAc dropped out of solution upon addition to water, and any attachment to the blade or the sides of the container occurred rapidly. The mixture was stirred for 15 min, the water was discarded, and the deposits were scraped off the surface, dried, and weighed. All measurements were made at least in duplicate, and the uncertainty was typically of the order of 10–30%, although higher variability was observed on occasion. Hence, the results should only be considered as semiquantitative. The stickies deposited out of solution in this study differ from those generated in a mill situation, where small stickie particles are formed through comminution, mainly in the pulper.

An attempt was made to separate deposits of PVAc mixtures with size exclusion chromatography with ultraviolet (UV) detection. However, mixtures of PVAc could not be separated since the nominal molecular weight of the "pure" PVAc was an average covering a range of molecular weights, and the signal from each pure PVAc was too broad to allow clean resolution from the other.

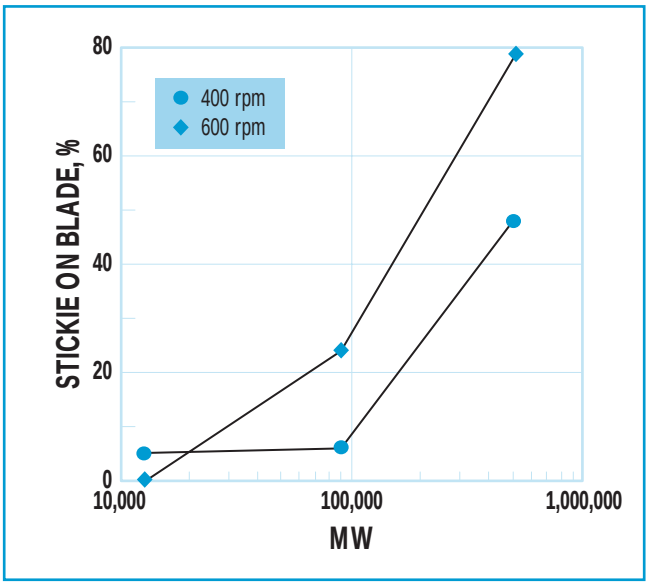
DEPOSITION OF STICKIES ON SURFACES IN THE ABSENCE OF FIBER

Pure PVAc

Deposition of PVAc increases with increasing molecular weight, as shown in **Figs. 1 and 2,** since the viscosity increases concurrently, and the more viscous material resists washout from the blade. Most of the variability in temperature and rpm in Figs. 1 and 2 can be reconciled through consideration of PVAc viscosity. Since increasing temperature lowers viscosity, deposition is either unaffected by, or decreases with, increasing temperature. Back previously identified viscosity as a major factor that determines the extent to which stickies can be sheared off surfaces *(10, 11, 13)*. He showed that pitch deposits from a sulfite pulp decreased with increasing temperature as a result of reduced pitch viscosity *(13)*.



1. Stickie deposition at 50°C



2. Stickie deposition at 70°C

MW	RPM	STICKIE ON BLADE, AVG. % Teflon	Metal
12,800	400	0	5.3
	600	5.0	0
90,000	400	2.7	3.1
	600	4.9	45
500,000	400	9.5	54
	600	8.2	73

I. Deposition of PVAc on the Britt jar blade (50°C)

Addition sequence	Stickie on blade, avg. %
90,000, 12,800	11
12,800, 90,000	8.7
90,000, 500,000	36
500,000, 90,000	25
12,800, 500,000	27
500,000, 12,800	18

*Run at 50°C at 400 rpm

*II. Effect of the sequence of addition on blade deposition**

The effect of stirring speed is straightforward for the MW 12,800 material in that the higher speed increases the washout tendency. Deposition of this polymer is low to begin with, and it mostly remains in the aqueous suspension. The MW 90,000 polymer exhibits more complex behavior, rising between 400 and 600 rpm, but decreasing on either side of the 600 rpm value in Fig. 1. The effect was reproducible. Back *(13)* noted a similar effect with pitch. Presumably, the influence of washout increases at higher rotational speeds. Substantial quantities of the MW 500,000 material attach to the blade under all conditions, probably because its higher viscosity enhances its resistance to washout. In summary, a low-molecular-weight stickie tends to stay in suspension, whereas increasing viscosity increases the degree of deposition on the blade.

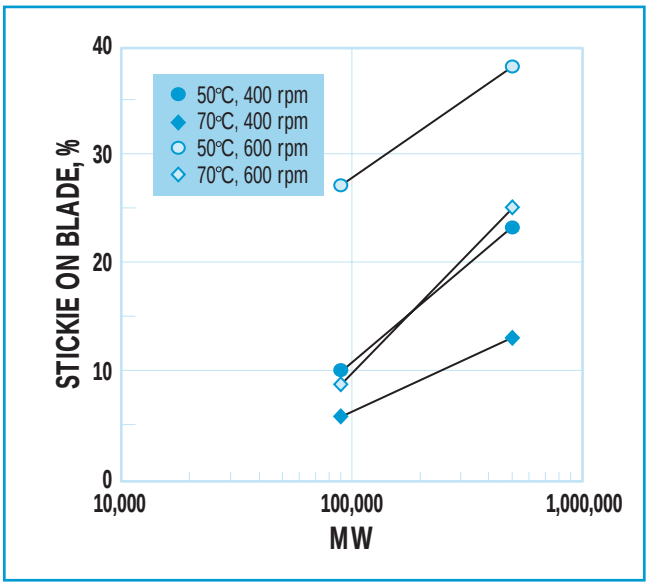
To determine the extent to which the blade material influences deposition, the metal blade of the Britt jar was substituted with one that was Teflon coated. The blade assembly consists of three circular paddles connected to a shaft. The metal paddles were 1.96 in. in diameter; the Teflon ones were 2.00 in. Hence, the Reynolds numbers were marginally higher for the Teflon blades. In general, deposition was lower on Teflon, as shown by the comparison in **Table I.**

Mixtures of PVAcs

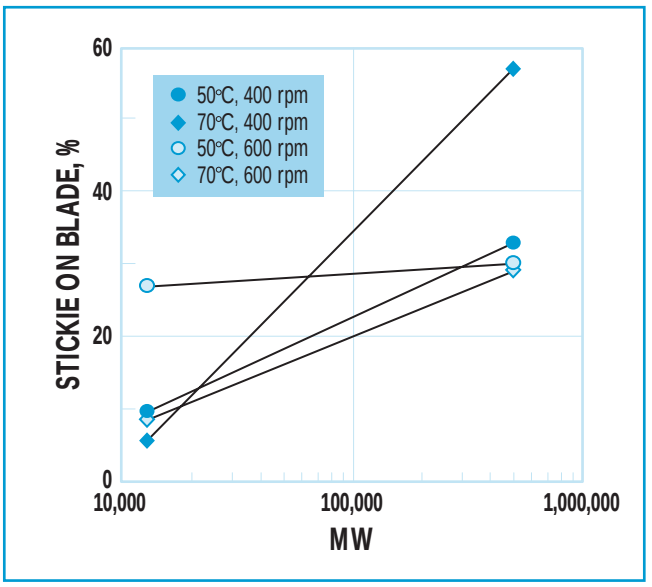
Since pure stickies are rarely found beyond the initial repulping operation *(14–16)*, measurements were made with mixtures of two stickies, which were prepared together in methanol and then added to the Britt jar. The results are presented in **Figs. 3–5.** For example, Fig. 3 presents data on mixtures of the MW 12,800 polymer with either the MW 90,000 material or the MW 500,000 stickie. Except for one case, the MW 90,000 and 500,000 mixture at 400 rpm in Fig. 5, deposition decreases with increasing temperature. Again, the effect of stirring speed alone is uncertain, with no clear trend emerging. However, the overall trend is the property of the PVAc mixture to be intermediate between those of its constituents.

While this is not true for all mixtures (as will be shown later for wax), it seems that the deposition properties of PVAc with components of different degrees of polymerization can be tailored through mixing. For example, the properties of an MW 90,000 polymer can be approximated by a mixture of MW 12,800 and MW 500,000 polymers.

Each pair of stickies used previously was dissolved in methanol and was, therefore, completely mixed when it deposited out of solution. Conceivably, separate addition of the stickies to the solution could alter deposition behavior, e.g., one stickie



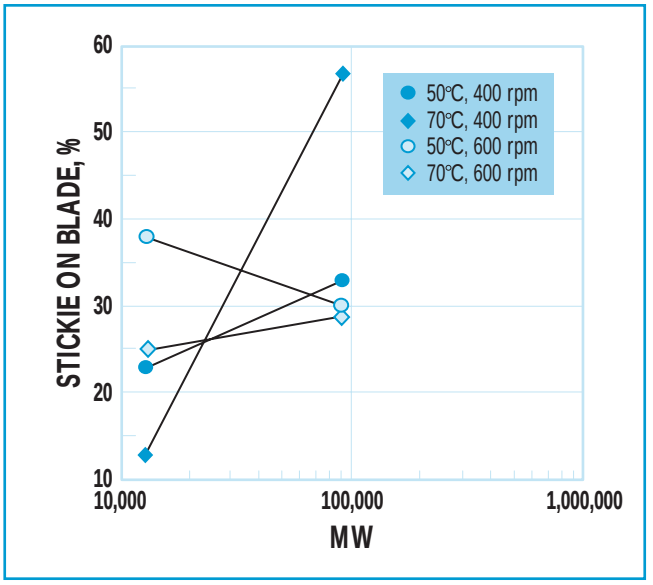
3. Deposition of MW 12,800 and (MW 90,000 or MW 500,000)



4. Deposition of MW 90,000 and (MW 12,800 or MW 500,000)

MW of PVAc mixed with wax	RPM	Temp., °C	Wax on blade, avg. %	Wax on sides, avg. %
12,800	400	50	21	30
	600	50	1.6	32
	400	70	1.9	10
	600	70	2.9	18
90,000	400	50	2.7	11
	600	50	13	50
	400	70	1.2	67
	600	70	0.5	10
500,000	400	50	4.2	13
	600	50	1.6	28
	400	70	0.5	22
	600	70	0.2	18

III. Deposition of wax/PVAc



5. Deposition of MW 500,000 and (MW 12,800 or MW 90,000)

could attach to the blade first, with the other then depositing on the attached stickie. Hence each PVAc was separately dissolved in methanol and added sequentially to water in the Britt jar. The results shown in **Table II** demonstrate that deposition is independent of the sequence of addition.

Wax

The previous approach was extended to 3040 Amber wax, 1 g of which was melted and added to water in the Britt jar. The wax, obtained from Astor Corp., had a nominal melting point of 54°C. In contrast to the PVAc work, most of the wax was found on the baffles and walls of the container. Some material was also attached to the impeller shaft at the air/water interface. We reason that the wax attaches to the first receptive surface that it encounters, and it resists washout. Since the area of the wall greatly exceeds that of the blade, the wax preferentially deposits there. Similar results were noted by Back *(13)*, who observed that viscosity played opposing roles in pitch deposition. On the one hand, low resin viscosity facilitates deposition; on the other, it promotes washout.

Mixtures of wax and PVAc were studied next to determine the extent to which PVAc modified the behavior of wax. Equal amounts (0.5 g) of wax and PVAc were melted together and added to water in the Britt jar and processed for 15 min. The results, shown in **Table III,** demonstrate complex behavior. For example, blade deposition of either pure wax or the MW 12,800 PVAc alone is small, whereas a substantial amount of a mixture of the two attaches to the blade at 400 rpm and 50°C. Presumably, the wax raises the viscosity of the mixture to the

Consistency, %	RPM	STICKIE ON BLADE, % MW 12,800	MW 90,000	MW 500,000
0.025	400	-	17	-
	600	0	71	0
0.05	400	0	0	-
	600	9.9	118	0
0.1	400	0	0	0
	600	0	0	0
0.2	400	14	0	0
	600	20	11	42
0.3	400	18	0	0
	600	1.3	23	0
0.4	400	2.6	0	0
	600	2.9	34	0
0.5	400	5.0	0	0
	600	18	0	0
0.6	400	8.2	0	0
	600	6.4	0	0

IV. Deposition of PVAc at 50°C in the presence of fiber

PVAc MW	RPM	AVG. % STICKIE ON BLADE CONSISTENCY, % 0.033	0.067	0.133	0.25
12,800	400	0	0.0046	0	0
12,800	600	0	0	0	0
90,000	400	6.6	0.0141	0.0032	0.0043
90,000	600	7.0	0	0	0
500,000	400	5.1	0.0647	0.0079	0.0055
500,000	600	9.9	0.0455	0	0

V. Effect of consistency on the blade deposition of PVAc

PVAc MW	RPM	STICKIE ON BLADE, avg. % Control*	With surfactant	White water
90,000	200	7	11	-
90,000	400	3	10	20
90,000	600	45	11	22
500,000	400	54	92	-
500,000	600	73	80	-

*No surfactant

VI. PVAc deposition in the presence of surfactant and in white water at 50°C

point where it can both deposit on the blade and resist washout. Blade deposition of the MW 500,000 material is reduced in the presence of wax, probably because the mixture resembles wax more than it does the PVAc. The important point is that unlike mixtures of PVAc, the properties of wax–PVAc mixtures are not necessarily intermediate between those of its components.

DEPOSITION OF STICKIES ON SURFACES IN THE PRESENCE OF FIBER

Stickie attached to fiber

PVAc (1 g) was melted on different amounts of linerboard, and the material was slushed with 1 L of water in a British disintegrator. The pulp (300 mL) was diluted with and equal volume of water and processed in the Britt jar at 50°C for 15 min. The material on the blade was then dried and weighed, and the results are presented in **Table IV.** Deposition of the MW 12,800 material increases slightly with increasing fiber content. For example, Fig. 1 shows no deposition at 50°C at 600 rpm in the absence of fiber, whereas appreciable amounts are found on the blade in Table IV at the higher consistencies. We attribute the difference to the fact that the fiber adds "body" to the stickie, in effect increasing its viscosity. In other words, when the fiber–stickie aggregate contacts the blade, the stickie bonds to the blade, and the fiber provides resistance to washout.

Deposition of the MW 500,000 polymer is reduced in the presence of fiber. This polymer has a sufficiently high viscosity to withstand shear, and the added fiber only serves to scour the stickie off the blade. The behavior of the MW 90,000 polymer is inconsistent. Under some conditions, the fiber induces greater deposition; in others, the amount is reduced. Highly variable behavior was also observed with this polymer in the absence of fiber (Fig. 1). It seems that the fiber can exhibit conflicting behavior. It can reinforce the deposition of low-viscosity materials by providing body. It can also reduce the deposition of more viscous polymers through its scouring action.

Stickie free from fiber

To isolate the scouring effect, measurements were made where the stickie was added to a pulp suspension. PVAc (0.2 g) in 10 mL of methanol was added dropwise to a 600-mL pulp suspension in a Britt jar at 50°C. The mixture was stirred for 15 min, and the material deposited on the blade was weighed. Although stickies comprised most of the deposits, fiber was also trapped on the blade. The deposits were dissolved in methanol, filtered to remove fiber, and dried, and the recovered residue was reweighed to give the stickies content. The results, listed in **Table V,** show that even at low consistency, the amount deposited is decreased substantially from the "no-fiber" results in Figs. 1 and 2. The effect is particularly strong for the MW 500,000 PVAc. The most likely explanation lies in the abrasive nature of the fiber referred to previously.

EFFECT OF SURFACTANT ON BLADE DEPOSITION OF PVAC

Inclusion of BRD2360 (a blend of fatty acids sold by Buckman as a flotation aid for secondary fiber recovery)

at 0.07 g/L in the Britt jar water did not materially alter deposition, as shown in **Table VI.** To determine whether surfactant hydrophobicity played a role, a set of surfactants of different hydrophilic lipophilic balance (HLB) values were obtained from ICI. A material with an HLB value of 2 was prepared from 8% Span 80 (sorbitan monooleate) and 92% of Span 85 (sorbitan trioleate). An HLB 16 material was prepared by mixing 60% of Tween 20 and 40% of Tween 80. The surfactant (0.04 g) was added to water (50°C) before introduction of the 90,000 PVAc.

The deposition appears to be independent of surfactant hydrophobicity. Measurements were also made with MW 90,000 PVAc and filtered white water from Riverwood International's coated board and linerboard lines at Macon, GA. These results, included in **Table VI,** indicate no major changes from the distilled water values. Hence, our results in water should apply, at least qualitatively, to a mill situation. We caution that these results only apply to PVAc and should not be generalized across all stickies.

CONCLUSIONS

Stickies tend to deposit on a surface because of their hydrophobicity, but washout increases with increasing shear. Fiber can accelerate washout through physical abrasion, although it can also reinforce deposition of a low-viscosity PVAc by strengthening its mat structure. Hence, for deposition to occur, the stickie must bind strongly to the surface and also have a high enough viscosity to resist washout. Since a low-molecular-weight stickie will usually be of low viscosity, it will tend to be washed out. On the other hand, the softening point of a material may be higher than the system temperature, in which case the material may have insufficient tack to attach to a surface. As might be expected, the behavior of stickies parallels that observed earlier for pitch *(10, 11, 13)*.

While it is certainly possible for a single stickie to have optimal properties for deposition, it is more likely that these properties can be reached through mixtures. As we have shown, the behavior of a mixture of stickies can be very different from those of their individual components. Stickie deposits in mills will usually be comprised of mixtures. Due to agglomeration, pure stickies are rarely found after the repulper *(14–16)*. This could explain why stickie outbreaks in mills occur suddenly and are usually difficult to trace to a particular load of furnish. Our findings suggest that a contaminant may induce stickie deposition by reinforcing the tack or viscosity of the stickie by mixing with it. Hence, the contaminant could induce deposition while only being present in small proportions. TJ

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